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Crystallization of photons via light storage in Rydberg gases

MATTHIAS MOOS, Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Germany, JOHANNES OTTERBACH, Physics Department, Harvard University, Cambridge, MA, USA, DOMINIK MUTH, MICHAEL FLEISCHHAUER, Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Germany — Rydberg atoms driven by light fields under conditions of electromagnetically induced transparency (EIT) can be described in terms of strongly interacting slow-light Rydberg-polaritons with tunable effective mass. In a 1D setting the physics can be described by a Luttinger liquid model. The Rydberg interaction gives rise to density-wave correlations decaying as a power law. For sufficiently strong interactions the density-wave becomes dominant, marking the onset of a quasi-crystalline photon state. We calculate the Luttinger K parameter using DMRG simulations and compare it to analytic approximations. We find that under typical slow-light conditions the interactions are too weak for crystalline order to emerge. However, adiabatically increasing the effective mass of the polaritons by turning them into stationary spin excitations allows to generate long-range crystalline order. This can be done by storing the polaritons in a stationary spin-wave. We analyze the dynamics of this process in terms of a time-dependent Luttinger theory and derive conditions for an optimal storage scenario.

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